# Ferrous Alloys for Fusion

## Exploration of the use of ferrous alloys as radiation damage resistant materials for fusion.

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This work explores the effects of the life-limiting factors on **breeder blanket structural materials in fusion reactors** and aims to expand the operational window of current steel options. Fe-based model alloys with varying levels of **Mn** and **Si** are investigated due to their contribution to **irradiation induced degradation** and **enhancement of clustering effects**.

## Introduction

Current fusion designs (primarily tokamaks in the UK) use steels to provide the structural integrity for the breeder blanket and its components. RAFM and ODS steels (including EUROFER) can satisfy most of the requirements and withstand the extreme environment to some extent [1]. However, it has been found that upon irradiation, elements, including Mn and Si, form clusters; little is known as to what effect these will have on the properties of the steel [2].

## Materials

Samples will be arc melted using high purity elements (>99.95%). Initially the following compositions (stated as wt%) will be trialled prior to refinement.

| Alloy name | Fe | Cr | Mn | Si |
|---|---|---|---|---|
| Fe8Cr | Bal | 8 | - | - |
| Fe8Cr0.1Mn | | | 0.1 | - |
| Fe8Cr0.5Mn | | | 0.5 | - |
| Fe8Cr1Mn | | | 1.0 | - |
| Fe8Cr0.1Si | | | - | 0.1 |
| Fe8Cr0.2Si | | | - | 0.2 |
| Fe8Cr0.5Si | | | - | 0.5 |

These compositions have been chosen to align with those used in the literature for EUROFER [3] and other similar steels used by industry for fusion applications.

## Methodology

Prepared using metallographic preparation techniques. After initial analysis, heavy ion or proton irradiation will be carried out to enhance clustering and other effects [4].

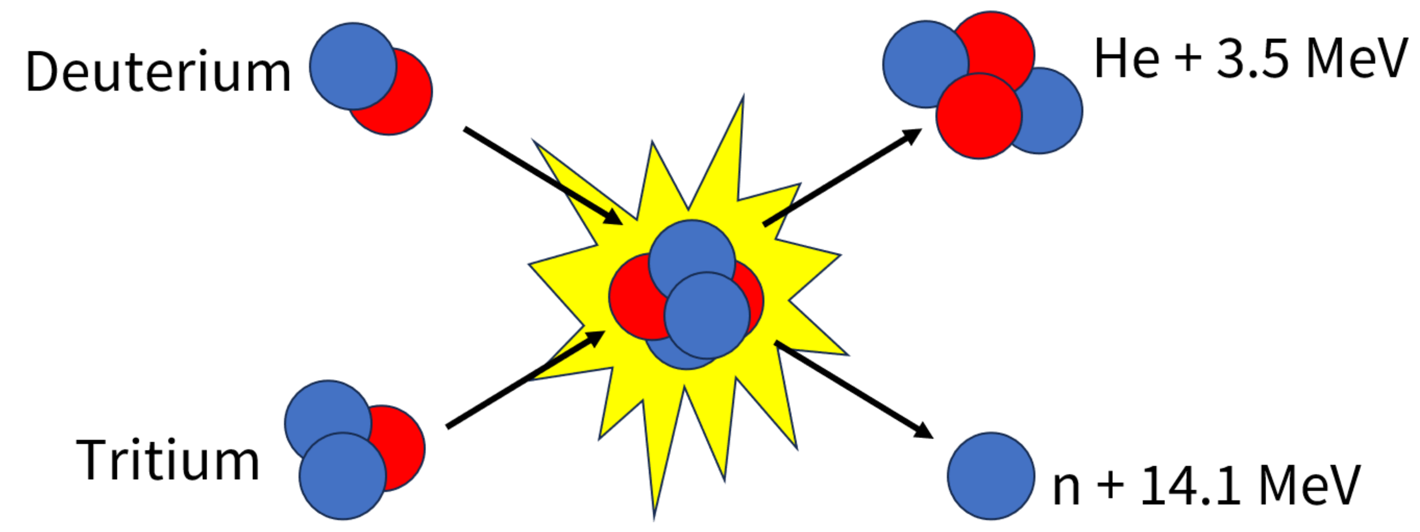
**Before irradiation:**

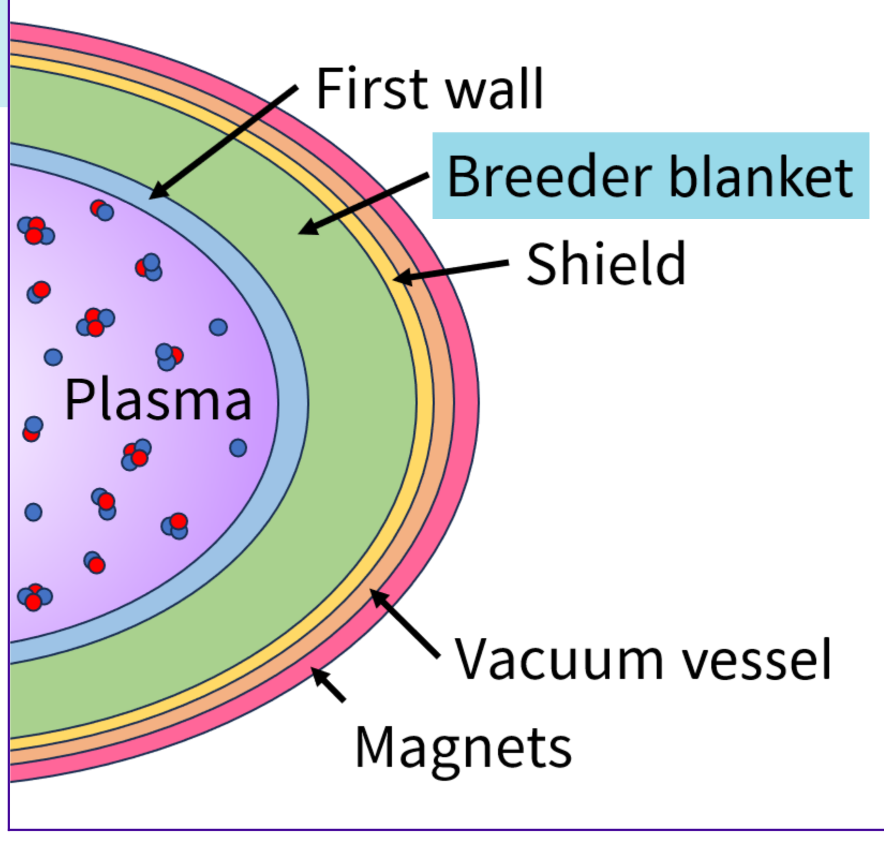
- Optical microscopy
- Scanning Electron Microscopy (SEM)
- Energy Dispersive X-ray (EDX)
- Initial measurements for swelling and embrittlement

**After irradiation:**

- SEM
- EDX
- Transmission electron microscopy (TEM)
- Atom Probe Tomography (APT)
- Swelling testing
- Embrittlement testing

## Nuclear Fusion



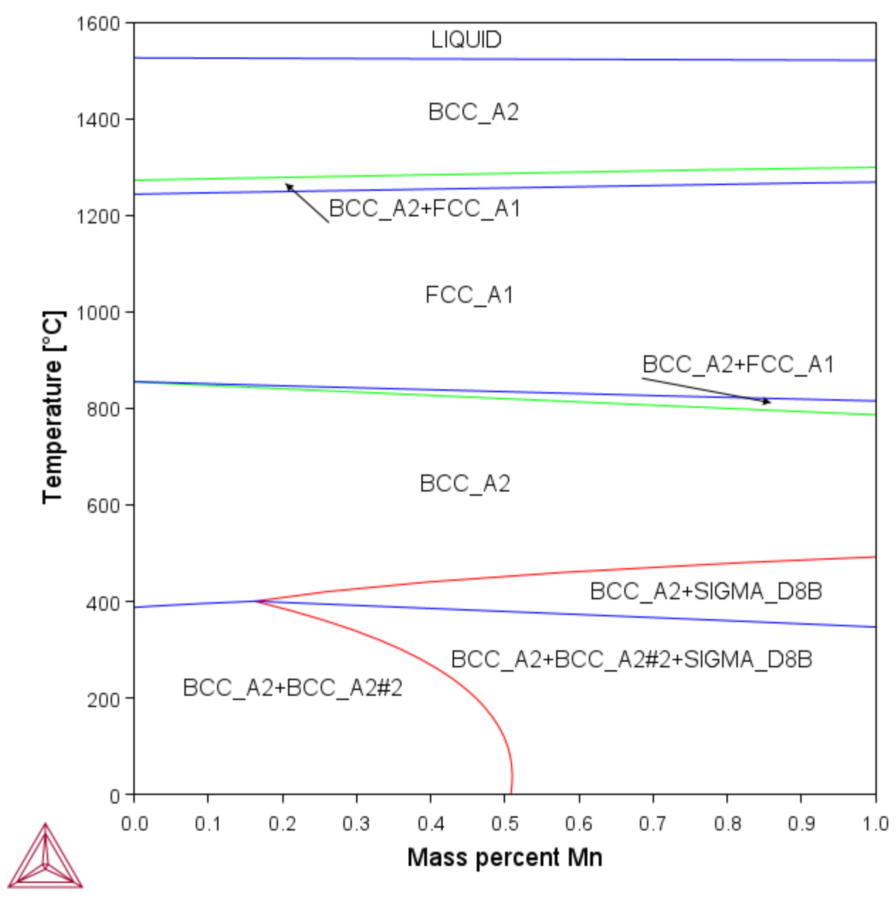



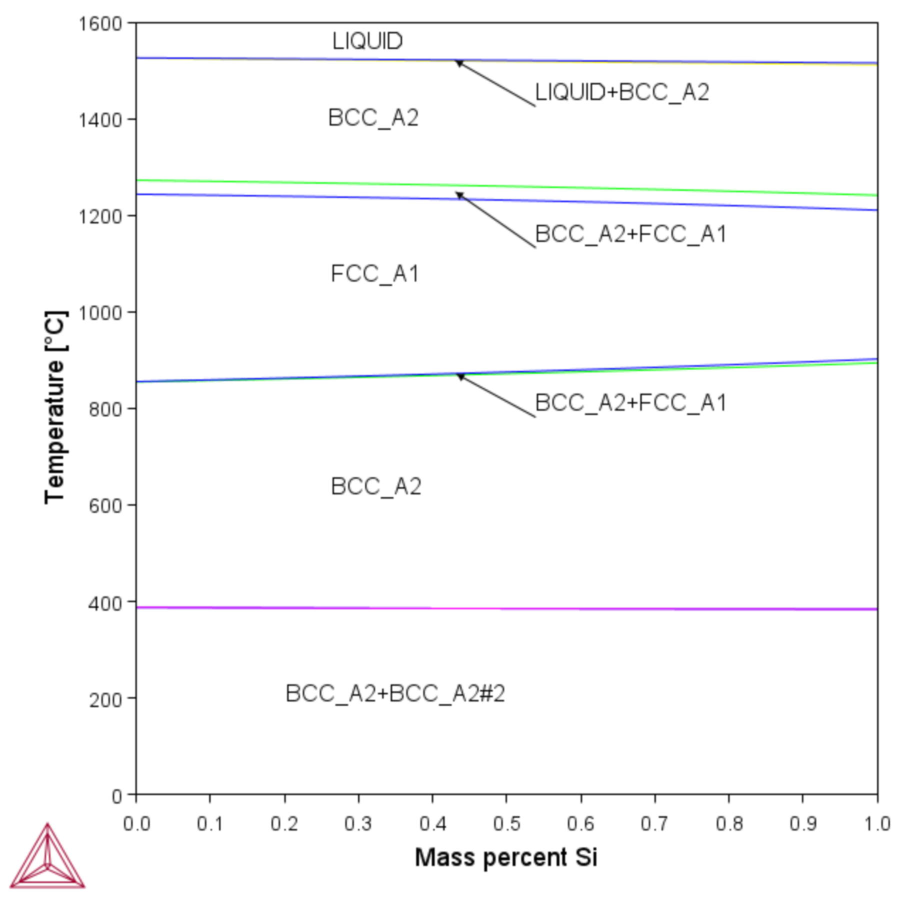

**Breeder blanket conditions:**

- High temperatures (550°C+)
- Radiation damage (100's dpa) and transmutation effects
- Tritium interactions
- Corrosion effects
- Creep effects
- Magnetic field interactions
- Waste considerations

## Modelling

ThermoCalc has been used to predict the phases that will be formed at the various desired compositions.
Within the composition ranges explored there is expected to be limited impact on the formation of different phases. Formation of sigma phase in Mn alloy will ideally be avoided due to brittle nature and lack of relevance to RAFM steels.




## Future Work

- Combination of optimised quantities of Mn and Si in same alloy
- Introduction of carbon into alloys – working towards closer simulation industrially applicable materials

## Bibliography

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